THE PRODUCTION OF REAL AND NON-WORDS IN ADULT STUTTERERS AND NON-STUTTERERS: AN ACOUSTIC STUDY

S. P. Whiteside, R. A. Varley, T. Phillips and H. Garety

Department of Human Communication Sciences, University of Sheffield, UK.

ABSTRACT

Dual-route models of speech production suggest that high-frequency forms are encoded in different ways from low-frequency and novel forms [7, 15, 16]. There is some evidence to suggest that lexical status may have some influence on stuttering behaviour, with higher incidences of stuttering being observed for low frequency words [4, 9]. This paper reports on a study, which investigated the production of high and low frequency words, and non-words in two groups of young adult males. The first, comprised a group of speakers with stuttering (N=4), and the second, speakers without stuttering (N=5). Three repetitions were elicited from each subject via a repetition task and recorded onto DAT. These data were subsequently digitised at a sampling rate of 20 kHz. Two parameters were measured (in milliseconds) from the digitised samples using a KAY Elemetrics Computerised Speech Lab: 1) Response latencies (time taken to respond to a stimulus); and 2) word durations (duration of utterance). We report here on the first repetition of the high/low frequency and non-words.

The results are presented and discussed with reference to implications for the production of frequent and novel forms, motor speech learning, and how motor speech disorders such as stuttering can shed some light on speech encoding mechanisms.

1. INTRODUCTION

The traditional conceptualisation of motor speech disorders is influenced by psycholinguistic models which suggest that the speech segment plays a critical role in the encoding of speech [1, 11]. In these models, speech encoding is viewed as a process of segment-by-segment access and the subsequent assembly of the syllable/word. Much of the empirical evidence for such theories rests on speech error data from normal speakers (e.g. segmental switches which convert ‘car park’ to ‘par cark’). Contemporary psycholinguistic models have, however, begun to challenge the role of the segment in speech production [7]. Levelt and Wheeldon [7] suggest that there are two possible routes in speech encoding: a direct1 route that operates via stored syllabic schemas, and an indirect2 assembly route that utilises sub-syllabic units. Direct route encoding is more likely to be used for higher frequency syllables and the indirect route for lower frequency, or novel syllables. Direct route encoding permits an efficient and relatively error free output as the multiple degrees of freedom of the speech motor system are constrained into schemas or gestural gestalts [5].

Acquired apraxia of speech (AOS) is a motor speech disorder that results from damage in the area of the pre-motor cortex in the language-dominant hemisphere. The characteristics of this motor speech disorder include: a slow rate of speaking [6]; inconsistent and variable articulatory movements [3] and disruptions in all production systems involved in the phonetic encoding of the linguistic message. These disruptions result in multiple phonetic and perceived phonemic errors in speech output, which therefore result in lowered speech intelligibility [14].

Varley and Whiteside [15] and Whiteside and Varley [16] suggest that as a motor speech disorder, AOS can usefully be re-conceptualised within the direct/indirect or dual-route theory hypothesis. They argue that in AOS, either the access to and/or the storage of syllable or word level verbo-motor patterns are disrupted, and that much of the abnormal speech behaviours of speakers with AOS represents an attempt to compensate for this fundamental processing impairment by a reliance on indirect mechanisms. They also suggest that indices of encoding route include parameters such as response latency, utterance and word durations and the degree of coarticulation, with increasing latencies and durations and decreasing coarticulation with indirect route encoding.

Some of the speaking characteristics that present in speakers with stuttering are similar in nature to those observed in speakers with AOS. These characteristics include initiation difficulties and groping behaviours, sound prolongations, slower speech rates, blocks, effortful speech production, variability in parameters such as voice onset time, and poor sensory processing [see 9 for a review of motor speech deficits in stuttering]. There is also some evidence to suggest that lexical status may have some influence on stuttering behaviour, with higher incidences of stuttering being observed for low frequency words during reading tasks [4].

This paper reports on an investigation of response latencies and word durations in the production of high frequency and low frequency words, and non-words across two subject groups: adults with stuttering (N=4) and adult without stuttering (N=5). The results are presented and discussed with reference to implications for the production of frequent and novel word forms, and how motor speech disorders such as stuttering serve to shed some light on speech encoding mechanisms such as those proposed within a dual-route hypothesis [7, 15, 16].

---

1 This is referred to as the ‘indirect’ route by Levelt and Wheeldon [7]
2 This is referred to as the ‘direct’ route by Levelt and Wheeldon [7]
2. METHOD

2.1. Subjects

Two subject groups participated in the study:

1) Speakers with stuttering\(^1\) (N=4, mean age=31 years). All speakers were from South Yorkshire, and were matched for accent. All subjects were either attending speech therapy or a self-help group for stutterers. All subjects completed a Perceptions of Stuttering Inventory (PSI) \[^17\]. PSI provides a descriptive analysis of an individual's stutter, and its score can therefore be used as an indicator of severity. The subjects' PSI scores are given in Table 1. Each subject's profile placed them in the categories of either symmetrically moderate (S4), or moderate to severe (S1 to S3).\(^4\)

2) Speakers without stuttering\(^5\) (N=5, mean age=25.2 years). All speakers were male, and although they were living in South Yorkshire at the time of the study, they were not matched for accent.

<table>
<thead>
<tr>
<th>Sub. ID</th>
<th>Struggle</th>
<th>Avoidance</th>
<th>Expectancy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>score</td>
<td>severity</td>
<td>score</td>
</tr>
<tr>
<td>S1</td>
<td>17</td>
<td>severe</td>
<td>8</td>
</tr>
<tr>
<td>S2</td>
<td>15</td>
<td>mod-sev</td>
<td>9</td>
</tr>
<tr>
<td>S3</td>
<td>12</td>
<td>mod-sev</td>
<td>18</td>
</tr>
<tr>
<td>S4</td>
<td>10</td>
<td>mod</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 1: The four subjects' scores on PSI \[^17\] for the three parameters: struggle, avoidance, expectancy. Each parameter has a maximum score of 20 points. mod=moderate.

2.2. Speech Data

Speakers repeated monosyllabic and bisyllabic words from a word list consisting of 24 phonetically matched high-frequency, low-frequency and non-word triads (e.g., boss-moss-muss). Frequencies were drawn from Thorndike and Lorge \[^13\] and Francis and Kucera \[^2\]. High-frequency words had more than 100 occurrences per million, and low frequency less that 10 per million. Each word appeared three times in randomised order. The data reported here includes only the first repetition of the data sets.

Data were recorded onto a Sony TCD-D3 DAT recorder in a quiet room.

2.3. Acoustic analysis

All speech data were digitized (Sampling Rate 20kHz) and analysed using a KAY Eilemetrics Computerized Lab (CSL) Model 4300. Speech pressure waveforms and wideband FFT spectrograms were used to obtain acoustic measures.

The measures that were taken were response latency and word duration. Response latency (or repetition latency) is generally used as an index of the planning time required for an utterance prior to its overt motoric implementation \[^10, 12\]. Response latency was therefore used in this study to investigate the effects of word frequency and novelty on phonetic encoding.

Word duration is assumed to reflect the planning time for the overt motoric production of a word \[^4, 10\].

Measurements of response latency and word duration were made as follows:

- response (or repetition) latencies (in milliseconds) - these were measured from the end of the experimenter's utterance to the start of the participant's utterance.

For the stutterers, occurrences of stuttering were noted and where stuttering behaviour\(^6\) consisted of word, or word initial sound repetitions, measurements of response latencies was taken at the subject's initiation of the response.

- word durations (in milliseconds) - these were measured from the start of the acoustic activity of the target word to the end of the word.

For the stutterers, the measurements of word duration were restricted to successfully initiated responses.

3. RESULTS

The mean and standard deviation values for response latency and word duration are given by word status for all the stutterers and non-stutterers are given in Tables 2 and 3, respectively, and depicted in Figures 1 and 2.

Data for the response latency and word duration of both the stutterers and non-stutterers were subjected to a repeated measures ANOVA test, to test for effects of word status (within-\[^6\] Incidences of dysfluency included sound-syllable repetitions, word repetitions, blocks, and sound prolongations.

---

\(^1\) From here, this group will be referred to as 'stutterers'.

\(^4\) Here 'symmetrical' is an indication that the stutterers' awareness of his/her own stutter, and its actual severity are approximately equivalent \[^17\].

\(^5\) From here, this group will be referred to as 'non-stutterers'.

---
subject effects), and to test whether there were any group differences (between subject effects). Results of multivariate tests indicated that there were significant within-subject effects for word status (F(4, 624)=20.94, p<.0001). Univariate tests for word status effects were found to be significant for both response latency (F(2, 312)=29.36, p<.0001) and word duration (F(2, 312)=6.89, p<.001). Multiple comparisons with Bonferroni adjustment were carried out to investigate the word status effects. Results of these comparisons indicated that the response latencies for the non-words were significantly longer than both the high, and low frequency words (p<.05). In addition, the word durations for the non-words were significantly longer than the high frequency words (p<.05).

In addition, significant group and word status interactions (F(4, 624)=7.80, p<.0001) were also found. These interaction effects included marked increases in the response latencies for the stutterers' non-words compared to those for the high and low frequency words (see Figure 1).

<table>
<thead>
<tr>
<th>Word status</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stutterers</td>
</tr>
<tr>
<td>High Frequency</td>
<td>576.59 (259.59)</td>
</tr>
<tr>
<td>Low Frequency</td>
<td>593.33 (102.04)</td>
</tr>
<tr>
<td>Non-words</td>
<td>710.29 (139.43)</td>
</tr>
</tbody>
</table>

Table 2: Mean and standard deviation values (in msec) for all three groups by word status: response latency.

Significant between-subjects effects were also found for group for both response latency (F(1, 156)=431.13, p<.0001), and word duration (F(1, 156)=33.09, p<.0001). These significant between-group differences were characterised by the stutterers displaying longer response latencies and word durations. These were both found to be significant using multiple comparisons with Bonferroni adjustment (p<.05) (see Figures 1 and 2).

<table>
<thead>
<tr>
<th>Word status</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stutterers</td>
</tr>
<tr>
<td>High Frequency</td>
<td>548.26 (242.71)</td>
</tr>
<tr>
<td>Low Frequency</td>
<td>566.49 (273.06)</td>
</tr>
<tr>
<td>Non-words</td>
<td>589.26 (260.01)</td>
</tr>
</tbody>
</table>

Table 3: Mean and standard deviation values (in msec) for all three groups by word status: word duration.

4. DISCUSSION

The data from the adult male stutterers and non-stutterers indicated that there were lexical effects for both groups of speakers in the production of high and low frequency words and non-words. Both the stutterers and non-stutterers displayed significantly longer response latencies for the non-words compared to the high and low frequency words. This suggests that both groups of speakers needed additional planning time for the encoding of non-words, and may have been relying on 'indirect' route mechanisms [15, 16]. The significantly longer response latencies for the non-words could however, be interpreted as some evidence for a greater reliance on 'indirect' route mechanisms in the speech encoding of the non-words, with greater planning time required for their production [15, 16]. Response latency however, is a difficult parameter to interpret. It is difficult to ascertain to what degree response latency is determined by either auditory recognition or motor encoding, or indeed both. Therefore it not clear whether the results reported here are evidence for differences in motor encoding and/or auditory recognition.
It has been suggested that dual-routes may be operating in speech encoding [7, 15, 16] with novel and low frequency words/syllables being largely reliant on 'indirect' mechanisms. There were significant word status effects with significantly longer word durations being found for the non-words, compared to the high frequency words. This and the absence of a significant difference between the word durations of the non-words and low frequency words could be interpreted as evidence in support of a reliance on 'indirect' mechanisms in the production of novel and low frequency word forms.

The significant group differences found between the stutterers and non-stutterers were characterised by the stutterers displaying significantly longer response latencies and word durations. This pattern was observed across the high and low frequency words and the non-words (see Tables 2 & 3, and Figures 1 & 2). This is suggestive of some level of impairment or compromised efficiency in the planning and production of the words by the stutterers. In addition, the fact that significant group and word status interactions were due to much longer response latencies for the stutterers' non-words, suggests that they needed additional planning time for the production of novel speech forms (see Figure 1). Motor learning impairment has been suggested as an underlying cause of stuttering [see 9 for review], a suggestion that is borne out by the findings here.

It has been suggested that high frequency words are more likely to be stored as whole-word schemata [15, 16]. The longer response latencies and longer word durations observed for the stutterers' high frequency words in their non-stuttered output could be interpreted as evidence for the impoverished nature of the stored motor schemata for even frequent word forms. Such an interpretation would be supported by the implication that motor learning impairment may be an underlying cause of stuttering [see 9].

This study reported significant lexical effects in a group of non-stutterers and stutterers, and replicated the frequency effects that have been reported previously for stutterers [4]. The observed lexical effects provided evidence in support of a dual-route hypothesis of speech encoding [7, 15, 16]. The results also shed some light on the underlying mechanisms that may be operating in the production of high and low frequency, and non-words. This study highlights the value of using evidence from motor speech disorders such as stuttering and AOS to inform debates on models of motor speech control and production [1, 4, 7, 9, 10, 11, 15, 16].

5. ACKNOWLEDGMENTS

The authors wish to thank all the participants and H. Luff for contributions to earlier phases of the investigation.

6. REFERENCES

7. Levelt, W. J. M. and Wheeldon, L. "Do speakers have access to a mental syllabary?", Cognition, 50, 1994, 239-269.
13. Thornbike, E. L. and Lorge, I. The Teacher’s Wordbook of 30,000 Words, Teachers College Columbia University, New York, 1944.